

**OLIVINE CRYSTALS AND THE PETROGENESIS OF THE APOLLO 15 OLIVINE-NORMATIVE MARE BASALTS: 2. MINERAL CHEMISTRY.** K. Nakamura<sup>1</sup>, K. Herrell<sup>1</sup>, G. Ryder<sup>1</sup>, and B. Schuraytz<sup>1,2</sup>. <sup>1</sup>Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058-1113, <sup>2</sup>now at Planetary Science Branch, SN4, NASA Johnson Space Center, Houston, TX 77058.

Our chemical analyses of a suite of 25 Apollo 15 olivine-normative mare basalt samples, using splits of 4 to 5 g, validated previous conclusions that the suite chemistry is controlled by olivine [1-8]. However, the simplicity of the chemical model is not matched by a corresponding simplicity of petrographic features, such as can be interpreted as a sequence that includes cumulate olivines and successive flow fractionates [7-8]. The question then is where the olivine separation that controls the chemistry of the Apollo 15 olivine-normative mare basalts took place, and how the samples came to crystallize to what they are now. In the present study (not yet complete) we are evaluating the characteristics of the olivine itself in an effort to constrain the crystallization and subsolidus histories of each sample. In an accompanying abstract (Herrell et al.) we discuss some of the petrographic characteristics and inferences; in this abstract we discuss some aspects of the compositional variation of the olivines as determined by microprobe analyses.

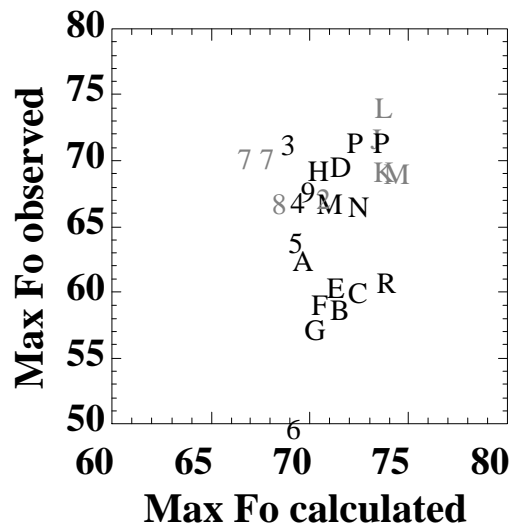
We have investigated the compositions of olivines in order to better constrain the cooling histories of samples, from initial crystallization through re-equilibrations during cooling of the magma and in the subsolidus. We have made analyses for the major elements as well as for Mn, Ca, and Cr which are significant minor elements (0.2-0.7 wt. %). We obtained some data for Ti, Al, and Ni which are present at much lower abundances (<0.05 wt.% oxides), but have so far only made precise analyses for the latter three elements for one sample. We have concentrated on the compositions of the core regions of the larger crystals in each sample, attempting to obtain an analysis of the most magnesian olivine in the sample. We have also analyzed some rim and interstitial olivine compositions, and made measurements along core-rim profiles.

In Figure 1 we plot the Fo content of the most magnesian olivine we found in a sample against the olivine we calculate would crystallize from a magma with the bulk composition of the rock, using accepted Mg-Fe partition coefficients for low-Ti mare basalts. Some of the samples plot close to the 1:1 line. For these samples, the data are consistent with each rock being a magma composition, that it first crystallized equilibrium olivine, and that subsequent cooling was fast enough that at least some of this first olivine did not re-equilibrate with the magma. Most of the finest-grained samples and several of even the coarse-grained samples fall within 3 mol % Fo of this line; the vesicular samples tend to be near it. However, many of the samples have much lower observed Fo than calculated Fo. There are several possibilities for this, the main ones being a) cumulate olivine of the measured compositions, which increase the magnesian content of the bulk rock and thus of the calculated Fo and b) re-equilibration during cooling (including the subsolidus) such that magnesian cores are eliminated by reaction with more iron-rich phases. While

another possibility is that we have simply failed to find the most magnesian olivines in our study, where others have analyzed some of these samples, the most magnesian olivines they report are similar to those we obtained (e.g. [6, 9, 10]).

Our petrographic analysis (Herrell, accompanying abstract) shows that the difference cannot be accumulation in at least most cases. For instance sample 15545 (B on Fig. 1) has only 5% olivine in non-groundmass grains, 15647 (E) only 6%, and 15598 (A) only 3.5%. Fine-grained sample 15119 (6) has very little olivine at all.

**Figure 1. Maximum Observed v. Predicted olivine composition for each sample.**

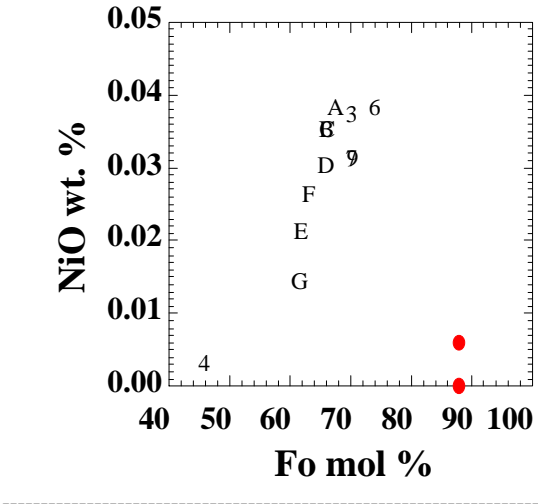


Thus the most likely cause of the lack of magnesian cores is re-equilibration, either during crystallization or subsolidus. This is perhaps consistent with the ragged boundaries of plagioclases and pyroxenes apparent in some samples; sample 15119, with the lowest Fo content of its olivines, has ragged silicate phases although it is fine-grained. In contrast, fine-grained (and vesicular) sample 15668 (2 on Fig. 1) has a subophitic texture with euhedral small laths of plagioclase and interstitial pyroxene and mesostasis. It is close to having its expected magnesian olivines (Fo68 cf. Fo72), even though the only thin section available has a very tiny surface area and only three olivine crystals as large as a few hundred microns across.

None of the olivines in any sample is completely homogenized, all showing continuous normal zoning. Even some of the coarse-grained rocks, such as sample 15555 [9], have undergone little homogenization from a probable original

crystallization profile. However, this suggests that the crystals did grow during crystallization at the surface, and that homogenous olivines (such as occur in extruded Hawaiian lavas) were not erupted and then re-equilibrated.

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**Fig. 2. NiO v. Fo for olivines in sample 15622.** (nb the letters do not correspond with those of Fig. 1)



In Figure 2 we plot Ni v. Fo for a few crystals in sample 15622 (L on Fig. 1) which is one of the coarser grained and one of the most magnesian samples. Its maximum observed olivine Fo content (74.5) is very similar to that expected (74.1) from a magma of its own composition.

The analyses were made with an acceleration of 20 keV, 100 nA beam current, and count times of ~100 seconds. The precision is best shown by the analyses of the Marjalahti pallasite olivine, which contains negligible Ni, analyzed at the same time (filled circles).

These data for 15622 olivines show a regular progression of decreasing Ni, which correlates with decreasing Cr, down to negligible Ni in the rims of the olivines. The bulk sample has ~75 ppm Ni (determined by both INAA and XRF), suggesting that olivine initially crystallizing from it should have NiO of 0.045 wt. % for a reasonable partition coefficient of about 5. We assume that it is safe to infer from this data that the olivine in this sample is not cumulate, but crystallized from a magma of the composition of the bulk rock. Thus discrete magmas that are high in MgO (such as 15622) as well as those low in MgO (such as 15556; 7 on Fig. 1) seem necessary. Cumulate olivine is not present even in the coarsest, most magnesian samples. More Ni data on other samples is needed to clarify the relationships.

**References:** [1] Rhodes J.M. et al. (1973) PLSC 4, 1127. [2] Chappell B.W. et al. (1973) EPSL 18, 237. [3] Mason B. et al. (1972) PLSC 3, 785. [4] Helmke P.A. et al. (1973) The Moon 8, 129. [5] Ryder G. et al. (1973) PLPSC 18, 273. [6] Shervais J.W. et al. (1990) PLPSC 20, 109. [7] Schuraytz B.C. et al. (1990) Meteoritics 25, 406. [8] Schuraytz B.C. et al. (1991) LPS XXII, 1199. [9] Walker D. et al. (197) PLSC 8, 1521. [10] Dowty et al. (1973) PLSC 4, 423.